New patent claims

1. Ion beam scanning system having an ion source device, an ion accelerator system that can be set to an acceleration of the ions required to obtain a maximum depth of penetration, and an ion beam guidance system (1) comprising an ion beam outlet window (2) for a converging centred ion beam (3), and a mechanical alignment system (4) for the target volume (5) to be scanned,
characterized in that
the scanning system (6) comprises energy absorption means (7) that are arranged in the path of the ion beam between the target volume (5) and the ion beam outlet window (2) transverse to the centre of the ion beam and comprises absorber wedges (13) that can be displaced transverse to the centre of the ion beam, a high-performance linear motor (8) for rapid driving of the absorber wedges (13) and beam-intensity-controlled depth-scanning with transverse displacement of the energy absorption means (7), so that depth-staggered scanning of volume elements (9) of a tumour tissue (11) can be carried out in rapid succession.

2. Ion beam scanning system according to claim 1, characterized in that the target volume (5) is a tumour tissue (11) surrounded by healthy tissue (10), wherein the depth of penetration (12) of the ion beam (3) is determined by the energy of the ions in the ion beam (3) and the deepest region of the tumour tissue (11) can be reached by means of the variable acceleration of the ions.

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3. Ion beam scanning system according to claim 1 or claim 2, characterized in that the scanning system comprises an electronic control system (14, 34) for the linear drive of the absorber wedges (13) and includes an ionisation chamber (16) for measuring the particle rate of the beam and moves the absorber wedges (13) closer together by a step, preferably of from 10 µm to 100 µm, when a predetermined particle count has been reached, which particle count may be different for each depth step, so enabling depth-staggered scanning of volume elements (9) of the target volume (5).

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4. Ion beam scanning system according to any one of the preceding claims, characterized in that the energy absorption means (7) comprise at least two absorber wedges (13) that can be displaced in opposite directions transverse to the centre of the ion beam.

5. Ion beam scanning system according to any one of the preceding claims, characterized in that the energy absorption means (7) comprise two absorber wedge assemblies (18) that can be displaced in opposite directions transverse to the centre (17) of the ion beam.

6. Ion beam scanning system according to any one of the preceding claims, characterized in that the system comprises an edge-delimitation device (20) having displaceable shutter elements (21) between the target volume (5) and the energy absorption means (7).

7. Ion beam scanning system according to any one of the preceding claims, characterized in that the scanning system comprises edge shutters (19) that can be adjusted separately in the manner of an iris diaphragm in order to delimit some of the edge of the ion beam (3) with respect to the target volume.

8. Ion beam scanning system according to any one of the preceding claims, characterized in that it comprises a patient table (22) that carries the target volume (5) and that can be displaced in a plane transverse to the ion beam (3) in two directions of co-ordinates during an irradiation procedure.

9. Ion beam scanning system according to any one of the preceding claims, characterized in that it comprises a patient table (22) that carries the target volume (5) and that can be displaced in a lateral direction transverse to the ion beam (3) during an irradiation procedure and has deflection magnets (23, 24, 25) that deflect the ion beam (1) from its central position at the outlet window (2) transverse to the lateral direction of the patient table (22).

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10. Ion beam scanning system according to any one of the preceding claims, characterized in that the intensity of the ion beam scanning is defined by the total number of ions that strike a volume element (9).

11. Ion beam scanning system according to any one of the preceding claims, characterized in that it has an ionisation chamber (16) for measuring the beam intensity, which is arranged upstream of the energy absorption means (7).

12. Ion beam scanning system according to any one of the preceding claims, characterized in that it comprises a patient table (22) that carries the target volume (5) and that can be displaced in a lateral direction transverse to the ion beam (3) during irradiation, and has a gantry system (27) that can be rotated about a gantry axis of rotation transverse to the lateral direction of movement of the patient table (22).

13. Ion beam scanning system having a gantry system (27) for aligning an ion beam (3) with a target volume (5) according to claim 13, characterized in that the ion beam (3) is supplied to the gantry system (27) in the gantry axis of rotation (28) and can be aligned with a target volume (5) by means of magneto-optics (23, 24, 25) at adjustable angles of from 0 to 360° in a plane orthogonal to the gantry axis of rotation (28) so that the ion beam (3) intersects the gantry axis of rotation (28) at an isocentre (29) of the gantry system (27), wherein the gantry system (27) comprises a target volume carrier (30) that can be displaced laterally in the direction of the gantry axis of rotation (28), the target volume (5) is arranged upstream of the isocentre (29) and energy absorption means (7), which are arranged radially upstream of the gantry system (27), define volume element scanning in the depth direction, the gantry system (27) defines angular volume element scanning in the lateral direction and the laterally displaceable target volume carrier (30) defines volume element scanning in the longitudinal direction, and target volumes (5) of any shape can be scanned by volume element by a combination of those three scanning means.

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14. Ion beam scanning system having a gantry system according to claim 13 or 14, characterized in that the target volume carrier (30) remains stationary during irradiation and deflection magnets (23, 24, 25) deflect the ion beam (3) in the gantry plane during irradiation.

15. Ion beam scanning system having a gantry system according to any one of claims 13 to 14, characterized in that the energy absorption means (7) comprise absorber wedges (13) that can be displaced tangential to the circle of rotation of the gantry system (27).

16. Ion beam scanning system having a gantry system according to any one of claims 13 to 15, characterized in that the energy absorption means (7) comprise at least two absorber wedges (13) that can be displaced in opposite directions tangential to the circle of rotation of the gantry system (27).

17. Ion beam scanning system having a gantry system according to any one of claims 13 to 16, characterized in that the energy absorption means (7) comprise absorber wedge assemblies (18) that can be displaced in a radially staggered manner tangential to the circle of rotation of the gantry system (27).

18. Ion beam scanning system having a gantry system according to any one of claims 13 to 17, characterized in that a central region of the target volume (5) is arranged upstream of the isocentre (29) by at least one fifth of the radius of the gantry system, so that the target volume (9) itself does not lie in the isocentre (29).

19. Method of ion beam scanning using an ion source device, an ion accelerator system and an ion beam guidance system (1) comprising an ion beam outlet window (2) for a converging centred ion beam (3), and a mechanical alignment system (4) for the target volume (5) to be scanned, characterized by the following method steps:

- setting of the ion accelerator system to an acceleration of the ions required to obtain a maximum depth of penetration (12),
- detection of the ion beam intensity,
- transverse displacement of energy absorption means (7) of variable thickness for depth modulation of the ion beam (3),
- summation of the radiation ions of a volume element (9) of a target volume (5) up to a predetermined radiation dose,
- alteration of the depth of penetration of the ion beam (3) by means of transverse displacement of the energy absorption means (7) when the predetermined radiation dose of the volume element (9) has been reached in order to irradiate the next upstream volume element.

20. Method according to claim 19, characterized in that an electronic control system (14) for the linear drive of the absorber wedges (13) measures the particle rate of the beam by means of an ionisation chamber (16) and moves the absorber wedges (13) closer together by a step, preferably by from 10 to 100 µm, after a predetermined particle rate has been reached, which particle rate may be different for each depth step, so that depth-staggered scanning of volume elements (9) of the target volume (5) is effected.

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21. ~~Method according to claim 19 or 20, characterized in that the intensity is adjusted to from 10^6 to 10^8 absorbed ions per volume unit during scanning of the target volume (5).~~

22. ~~Method according to any one of claims 19 to 21, characterized in that the scanning of the volume of the target volume (5) progresses continuously.~~

23. ~~Method according to any one of claims 19 to 22, characterized in that the scanning of the target volume (5) in the depth direction is effected in columns.~~

24. ~~Method according to any one of claims 19 to 23, characterized in that the scanning of the target volume (5) proceeds stepwise.~~

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25. Method according to any one of claims 19 to 24, characterized in that the scanning of the target volume (5) is carried out continuously in the depth direction and stepwise in the lateral and longitudinal directions.

26. Method according to any one of claims 19 to 27, characterized in that the scanning of the volume of the target volume (5) is carried out continuously in the depth direction and in the lateral direction and stepwise in the longitudinal direction.

27. Method of operating an ion beam scanning system according to any one of claims 19 to 26 using a gantry system (27) for aligning an ion beam (3) with a target volume (5), wherein the ion beam (3) is supplied to the gantry system (27) in the axis of rotation and is aligned with a target volume (5) by means of magneto-optics (23, 24, 25) at adjustable angles of from 0 to 360° in a plane orthogonal to the gantry axis of rotation (28), so that the ion beam (3) intersects the gantry axis of rotation (28) at an isocentre (29) of the gantry system (27), wherein the gantry system (27) comprises a target volume carrier (30) that can be displaced laterally in the direction of the gantry axis of rotation (29),

characterized by the following method steps: arrangement of the target volume (5) upstream of the isocentre (29),

scanning of the volume element in the depth direction by means of energy absorption means (7) arranged radially upstream of the gantry system (27), scanning of the volume element in the lateral direction by altering the angle of rotation of the gantry system (27), and scanning of the volume element in the longitudinal direction by lateral displacement of the target volume carrier (30).

28. Method of operating an ion beam scanning system according to any one of claims 19 to 26 using a gantry system (27), in which a target volume carrier (30) is aligned before irradiation and remains stationary during irradiation and the ion beam (3) is deflected in the gantry plane by means of the last gantry

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deflection magnets (23, 24, 25) in order to carry out volume element scanning in the longitudinal direction.